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Below the surface: The application of implicit morpho-graphic regularities to novel word spelling

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Abstract Previous corpus studies have shown that the English spelling system is 'morpho-graphic' (Berg and Aronoff 2017) in that affixes are spelt in a consistent way (e.g., ‹ous› in *famous*) that distinguishes them from homophonous word endings without grammatical function (e.g., ‹us› in *bonus*). The present paper investigates if English spellers apply these regularities to the spelling of novel words implicitly and whether the application of those regularities is modulated by experience with the English writing system.

Participants with varying degrees of expertise in the English writing system were asked to spell novel words ending in /əs/, which were presented orally in either an adjective context (i.e., biasing towards the affix spelling ‹ous›) or a noun context (i.e., biasing towards an alternative spelling such as ‹us›). The results showed that the adjective context elicited significantly more ‹ous› spellings than the noun context, indicating that participants applied morpho-graphic spelling regularities to novel words to mark the appropriate lexical category. Additionally, there was a modulation by spelling ability: The higher participants' expertise in the English spelling system was, the more novel words they spelt according to morpho-graphic spelling regularities.

In conclusion, English spellers are aware of the morpho-graphic spelling regularities without explicit instruction and apply these to novel words. They gradually induce the regularities from the input, which results in more robust rule application with increased experience and expertise in the English writing system.

Keywords Morpho-graphic spelling · Novel word spelling · Derivational morphology · Psycholinguistics · Spelling ability

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The English spelling system has the reputation of being notoriously difficult to acquire – or even 'chaotic', as famously exemplified by Gerard Nolst Trenité (1922) in his poem "The Chaos", in which he contrasts words that are spelt similarly but pronounced differently (e.g., *though* vs. *through* vs. *cough*, with the letter sequence ‹ough› being pronounced /əʊ/, /u:/ and /ɒf/ respectively),[1] reflecting the opaque nature of the English spelling system (compared to other more transparent ones such as Italian).

This opacity with respect to grapheme-to-phoneme as well as phoneme-to-grapheme correspondences may affect different graphemes and phonemes to varying degrees. For instance, vowels are especially affected – in both directions: First, the letter ‹a› is pronounced differently in *fate*, *pat* and *wash* (i.e., as /eɪ/, /æ/ and /ɒ/ respectively) and, second, the diphthong /aɪ/ is represented by different letters in the words *mine*, *pie*, and *my* (i.e., ‹i›, ‹ie› and ‹y› respectively; cf. (Gontijo et al. 2003)). Gontijo et al. (2003) quantified the grapheme-phoneme correspondences, using the CELEX corpus (Baayen et al. 1995) to identify possible pronunciations of all graphemes in British English to establish a measure for orthographic depth. With respect to the grapheme ‹a›, for instance, they found that around 50% of occurrences are pronounced as /æ/ while the remaining 50% have a further 8 different pronunciations, thus being pronounced more variably than consonants, most of which have one or two pronunciation variants.

Crucially, graphemes should not be considered in isolation as the choice of grapheme or grapheme sequence is conditioned by neighbouring phonemes and graphemes. Kessler and Treiman (2001) showed that, for English monosyllabic (and morphologically simplex) words, the spelling of the syllable's nucleus is heavily dependent on its coda. For instance, with respect to the above grapheme ‹a›, the pronunciation /æ/ is the default, whereas empty codas or codas with ‹r› lead to pronunciation as /ɑ/ and codas with ‹l› to pronunciation as /ɔ/, amongst others.

Beyond graphemes and phonemes, there are larger units that have an influence on spelling in English. For instance, the spelling might reflect a word's etymology (e.g., preserving the letter ‹b› in *doubt*, which originates in the Latin verb *dubitare* 'to hesitate') or morphological relationships (e.g., the derived noun *health* retains the ‹ea› from its base *heal* despite the pronunciation change). With respect to the latter, in addition to the root consistency effect as in the *heal–health* example (Nagy and Anderson 1984), inflectional affixes are spelt in a consistent way – and differently from homophonous sequences without grammatical function (e.g., Carney 1994). For instance, word-final /z/ is represented by the letter ‹s› for plural nouns such as (*eye*)*brows* and *bries*, whereas other letter sequences such as ‹se› and ‹ze› are used in morphologically simplex words, as in *browse* and *breeze*, which are homophonous with the inflected examples (for a systematic corpus analysis of the affixes *-s* and *-ed*, see Berg et al. 2014).

Similarly, Berg and Aronoff (2017) showed the same spelling consistencies for four derivational suffixes. For example, the spelling ‹ous› for the word-final sequence /əs/ is only used in adjectives (e.g., *famous*, *joyous*), while the same final sequence

[1] Throughout the paper, angled brackets are used to represent letters or letter sequences and slashes are used for phonetic transcriptions.

is represented by other letters in other lexical categories (e.g., ‹us›, ‹is› or ‹ice› in the nouns *bonus*, *tennis* and *office*, respectively). As a result, the spelling system can be more informative than spoken language and might allow readers to capitalise on this additional information in language processing (e.g., by reducing ambiguities and easing lexical category assignment). Crucially, though, these regularities in the spelling of affixes – or what Aronoff et al. (2016) term 'morpho-graphic spelling' – were not implemented through prescriptive pressures but, according to Berg and Aronoff (2017), developed naturally in a self-organised process and are usually not taught explicitly to readers. As a consequence, if readers are aware of these morpho-graphic spelling regularities, they must have induced them from the input through exposure.

When it comes to spelling (i.e., the 'translation' of spoken language into written format), there are generally two routes through which this could be achieved: Firstly, via accessing the lexical entry with information about a word's orthographic representation and, secondly, via phoneme-grapheme correspondences, which may be more or less transparent depending on the language in question. These two routes have been shown to interact for the spelling of existing words. For instance, Delattre et al. (2006) report faster spelling times for words with high-probability phoneme-to-grapheme correspondences compared to those with low-probability ones, indicating that the sublexical route (i.e., via phoneme-grapheme correspondences) must be accessed here.

The more interesting test case for the nature of the sublexical route is the spelling of nonwords, for which the lexical route is not applicable as there cannot be a lexical entry for these novel words. Barry and Seymour (1988), for instance, demonstrated that participants tended to spell nonwords containing the phoneme /i:/ with ‹ea› or those containing /u:/ with ‹oo›, both of which represent the most common spelling of the respective sound. As seen above, the reliability of grapheme-phoneme correspondences may differ for individual sequences (e.g., the ‹ea› spelling is used to a similar degree as the second-most frequent spelling ‹ee› [40 vs. 39%], whereas the frequency difference is more pronounced for ‹oo› vs. ‹ew› with 48 vs. 10%).

Consequently, more context should be taken into account. More specifically, for word-final sequences, morphological information is, as pointed out above, relevant, leading to morpho-graphic spellings such as ‹ed› for past tense and ‹ous› for adjectives in contrast to alternative, non-morphological spellings such as ‹t› or ‹d› and ‹us› or ‹is› respectively. There have been several studies investigating whether developing readers/spellers are aware of such implicit regularities of the English spelling system when it comes to inflectional affixes. Looking at the spelling of word-final /d/ and /t/, Nunes et al. (1997b) observed that 6-to-9-year-old children spelt both past-tense verbs (e.g., *called*, *slept*) and nonverbs (e.g., *bird*, *soft*) phonetically before discovering the spelling ‹ed›, which they initially used not only for regular verbs but also, incorrectly, for irregular verbs (e.g., *sleped* for *slept*) and nonverbs (e.g., *sofed* for *soft*). After an intermediate stage with overregularisations being restricted to verbs (i.e., regular and irregular forms), the children finally reached the target-like distribution of ‹ed›. Importantly, in a study with novel verbs and nonverbs, Nunes et al. (1997a) found the same pattern, ruling out confounds due to knowledge of the individual items and the memorisation of their spelling.

However, there are always several factors that need to be taken into account for the decision for a specific spelling. For instance, there are additional restrictions with respect to which letters may or may not appear together and the grammatical context needs to be analysed correctly to decide with which type of word (e.g., which lexical category, singular vs. plural, tense) one is confronted. With respect to the former, Kemp and Bryant (2003), looking at the spelling of word-final /z/ in real and novel words in plural versus non-plural contexts, included a phonotactic constraint in their design: While the letter ‹z› never appears following voiced consonants in English (e.g., *‹bz›), there are different spellings of the phoneme /z/ following long vowels (e.g., ‹s› in *fleas*, ‹se› in *please*, ‹ze› in *breeze*). What Kemp and Bryant found was that both children and adults were more accurate using the ‹s› spelling for plurals when both the morphological context and the phonological constraint aligned. For instance, participants spelt the majority of consonant-final novel words such as /pli:nz/ as ‹pleens› in the plural context (i.e., when the ‹z› spelling was discouraged both by sentence context and the statistical information that ‹z› does not appear after voiced consonants), while vowel-final novel words such as /pri:z/ elicited fewer ‹s› spellings and more alternative such as ‹preeze› or ‹prease›. Interestingly, children who were good spellers in general and those adults with university education (i.e., current students, who were exposed to large amounts of reading and writing on a daily basis) were better at using the morphological information in the more difficult context of long vowels, suggesting that there are individual differences with respect to the use of specific types of information.

Importantly, spelling regularities for inflection (especially plurals and past tense formation) are very regular and transparent, applying across the board, which is why these rules are often taught explicitly in the classroom. Therefore, it is important to look at more implicit rules that are less likely to be addressed explicitly in the spelling acquisition process: Morpho-graphic spelling of derivational suffixes in adults who have fully acquired the English spelling system. This is what Ulicheva et al. (2020) did, testing whether skilled readers make use of morpho-graphic spelling regularities to induce the grammatical category of novel words, both in comprehension and production. In a categorisation task, they showed that participants were more likely to classify novel words with suffixes that are diagnostic of adjectives (e.g., *-able*, *-ous* and *-less* in *gufable*, *raxous* and *jevless*) as such, while novel words with nominal suffixes (e.g., *-ment*, *-an* and *-er* in *vixment*, *dofan* and *jumer*) were rather marked as representing nouns, suggesting that skilled readers' comprehension of novel words is aided by morphological information encoded in affixes with highly reliable spellings.

In a spelling production task, Ulicheva et al. also found that skilled readers make use of lexical category information provided by sentential context to spell final sequences of novel words in accordance with morpho-graphic spelling regularities. For instance, participants were more likely to spell the final sequence /əs/ with the affix spelling ‹ous› in the novel word /wɪvəs/ in (1), where it appears in an adjective context, than in /ɪptəs/ in the noun context in (2).

(1) The morning air smelled /wɪvəs/ as they walked through the countryside.

(2) The pilot warned that significant /ɪptəs/ was likely during the landing.

(Ulicheva et al. 2020, Appendix C)

Importantly, Ulicheva et al. found the effects (both in the categorisation and the spelling task) to be stronger for those affixes that had highly reliable spellings (i.e., that only occurred for the word class marked by the derivational affix and not another), suggesting that skilled readers acquired "knowledge [about] the statistical structure of the writing system [...] [through] implicit statistical learning processes" (p. 13).

However, neither of the studies above reported ceiling effects (i.e., perfect application of the implicit rules). More specifically, even in cases of highly reliable spellings such as ‹ous› for adjectives ending in /əs/ (vs. alternative spellings for nouns), Ulicheva et al.'s participants only produced the affix spelling in 29% of cases in the adjective context (Ulicheva, personal communication) – where, if the statistical information was fully implemented, one would expect a close-to-ceiling production of ‹ous› spellings. Similarly, the production of plural ‹s› spellings in Kemp and Bryant's (2003) vowel context did not exceed 64 percent, indicating that both statistical grapheme-phoneme information and grammatical context interact.

Crucially, in both novel word spelling studies, two types of information interact: Knowledge about statistical characteristics of grapheme-phoneme correspondences and identification of relevant grammatical information in the context. More specifically, for novel word spelling to reveal participants' knowledge about the spelling system as intended, participants have to complete three steps: Firstly, they have to identify the target phonemes in the input (e.g., /əs/ or /z/). Secondly, they have to utilise the context to identify which word class (e.g., adjective for /əs/, noun for /z/) and word form (e.g., singular vs. plural) are required. Lastly, they have to map the phonemes onto graphemes, weighing different types of information (i.e., general correspondences and specific rules depending on the sentence context or neighbouring phonemes). Only when all of the above steps have been completed, can we expect knowledge of implicit spelling regularities to be evident.

Following from this, the present study aims to investigate whether the amount of morpho-graphic spellings can be increased by experimental manipulations, making it easier for participants to identify and utilise grammatical context information. Therefore, the present novel word spelling study made the following four modifications compared to Ulicheva et al.'s design: (1) Simple predictable sentence contexts were used in order to avoid potential influences of semantic processing of other material in the experimental sentences and to make the intended word class of the novel word very predictable. (2) Instead of presenting only the novel word orally (i.e., in isolation, with the context sentence presented visually on the screen), participants listened to the novel word within the sentence context to increase the integration of the novel word into the context. (3) In order to avoid confounds due to idiosyncrasies of individual novel words (e.g., associations with existing words due to phonological similarities), each novel word was presented in both a context that was predicted to elicit the affix spelling and one that was not (using a Latin Square design). (4) In order to increase power, only one affix was investigated, namely *-ous*. This affix was selected because it is highly indicative of adjectivehood (see Berg and Aronoff 2017) and yielded the clearest differentiation between congruent (ADJ) and incongruent (N) contexts in Ulicheva et al. (2020).

Furthermore, the present study investigated the influence of individual differences on the application of morpho-graphic spelling regularities, following up on Kemp

and Bryant's (2003) observation that better spellers were more likely to make use of morphological information. As a measure of expertise with the English spelling system, a general spelling measure was included in the statistical analyses. As inducing morpho-graphic spelling regularities from the input likely depends on the amount of input a speller receives, the present study included participants who have less experience with the English writing system (i.e., they have had less time to make statistical inferences about the English spelling system). These were advanced learners of English, who form a group that is comparable to the tested adult native English spellers with respect to other variables such as educational background (compared to the alternative of native English adults with lower academic achievement) and cognitive abilities (compared to the alternative of children).

With the above modifications of Ulicheva et al.'s (2020) design, we aim at making the word category information that is crucial for the application of morpho-graphic spelling regularities more easily accessible for participants, who are expected to use significantly more morpho-graphic ‹ous› spellings in the appropriate adjective context (compared to a noun context). Nevertheless, there will, in all likelihood, also be alternative spellings. Predictions as to which alternative spellings (e.g., ‹us›, ‹is›) will be chosen most commonly are difficult to make solely based on simple phoneme-grapheme correspondences because the vowel of interest (i.e., /ə/) is a reduced vowel, which could be represented by nearly all vowel graphemes in unstressed syllables. However, as Berg and Aronoff's (2017, p. 45) corpus analysis revealed ‹us› to be the most frequent spelling for the final sequence under investigation (18% of types) after morpho-graphic ‹ous› (52% of types), this is the spelling that is expected to occur most if the morpho-graphic spelling is not applied.

Furthermore, when it comes to the integration of different types of information (i.e., context and morpho-graphic regularities), we expect better spellers to be at an advantage because, with spelling regularities firmly rooted, they have more resources left for the integration of different types of information. If awareness of morpho-graphic spelling regularities depends on the amount of experience with the writing system, less experienced and 'poorer' spellers might show a lower percentage of morpho-graphic spellings.

1 Participants

Overall, there were 96 participants (30 male, mean age = 27.12) with different degrees of exposure to the English writing system who took part in the study. Of these, 42 were native speakers of English (21 male) and the remaining 54 were students of English at the University of Braunschweig, 49 of which had German as L1 (9 male).[2] Participant characteristics are provided in Table 1. The native speakers were recruited amongst students and staff at the University of Reading, UK, and the University of Braunschweig as well as the English-speaking community in Braunschweig, Germany. Participants were paid for their time or received course credit.

[2] An additional participant was tested. However, her data was not included because it turned out that she did not study English (also reflected in a low LexTALE score).

Table 1 Participant information

	Experienced spellers (L1)		Inexperienced spellers (L2)		
	Mean (SD)	Range	Mean (SD)	Range	Difference
Age	33.02 (10.71)	17–59	22.54 (2.25)	19–29	10.48*
Age of Acquisition	0	–	7.94	2.5–11	–
Spelling Ability (%)	62.43 (20.94)	16.67–96.67	46.11 (23.40)	6.67–96.67	16.32*
LexTALE Score (%)	92.35 (7.21)	68.75–100	80.63 (9.80)	61.25–98.75	11.72*

* $p < .05$ (independent samples t-test)

2 Materials

For the experimental items, twenty four-letter nonwords with orthographic CVCC, CCVC or CVVC[3] structure that could be pronounced with an additional final /əs/ sequence were selected from the data base of the English Lexicon Project (Balota et al. 2007). While the written forms with the non-morphological spelling ‹us› all contained 6 letters (e.g., ‹cradus›, ‹lazzus›), the phonological forms consisted differed between five (e.g., /læzəs/) and six (e.g., /krædəs/) phonemes. As established using the ClearPOND database (Marian et al. 2012), most of the experimental items did not have any phonological neighbours—with the exception of ‹purnus› (1 neighbour: ‹purpose›) and ‹vushus› (2 neighbours: ‹luscious›, ‹vicious›). For a full list of the experimental items, see Table A1 in the Appendix.

Each novel word was presented in a short description of a character, whose name was established in the introductory sentence (50% male, 50% female). The description in the syntactic context of the second sentence then identified the novel word either as an adjective (see (3a)) or as a noun (see (3b)) to test whether the information about the syntactic category of the novel word is used for the decision for an ‹ous› spelling in contrast to an alternative spelling (e.g., ‹us›). The sentence contexts were kept simple (i.e., all sentences used “is very” and “is a” respectively) in order to decrease possible semantic interference from other material in the sentence and allow participants to make maximal use of the word class information of the novel word provided by these contexts.

(3) This is Amy.
   a. *She is very* /krædəs/ (adjective context)
   b. *She is a* /krædəs/ (noun context)

If participants are aware of the implicit morpho-graphic spelling regularities, they are expected to produce more ‹ous› spellings, indicating adjective status, in a context in which the novel word is presented as adjective compared to the noun context.

In addition, forty five-to-seven-letter words were selected as fillers. Thirty of these ended in one of four common orthographic sequences associated with potential consonant doubling (i.e., ‹id›, ‹it›, ‹le›, ‹ow›), in order to draw attention away from the

[3] C = consonant, V = vowel.

repeated /əs/ sequence in the experimental items. The remaining ten items contained the vowel /i:/, a notoriously difficult sound for spellers as there are a multitude of different spellings for it (e.g., ‹e›, ‹ea›, ‹ee›, ‹ei›, ‹ie›, etc.). Half of the fillers appeared in a verb context (following the modal verb *can*), and the other half either in an adjective or a noun context, thus ensuring that each context appeared in a third of the total of 60 trials.

Stimuli were recorded by a male native speaker of American English, who was unaware of the study's purpose. The native speaker had a list of orthographic forms of the novel words, with the experimental items spelt with ‹us› to avoid any potential bias in the pronunciation towards the affix spelling. The novel words were recorded in isolation, with the experimental and filler items mixed to prevent the detection of patterns in the stimuli, and were later spliced into the sentence contexts using the software Audacity (version 2.1.3, Audacity Team 2017). This way, the context sentences were the same across items and the critical novel words were identical in the two conditions.

3 Procedure

Participants were tested individually in a quiet room. For the *novel word spelling task*, they were seated in front of two laptop computers with 15" screens. One computer played the auditory stimuli, to which participants listened through headphones, and displayed the context sentence in black writing on a white background (font size: 28) controlled by the DMDX software (Forster and Forster 2003). The second sentence was repeated after a short pause to enable participants to listen to the novel word for a second time. On the other computer, participants typed the novel word into a simple text editing programme next to the provided trial number, with spell-checking software disabled. Participants were asked to review their spelling in order to avoid typos and proceed to the next trial when they were ready to do so. The task lasted approximately 20 minutes.

In addition to the main experiment, two additional measures were taken:

Spelling ability was measured based on 30 words taken from Burt and Tate's (2002, Exp. (3)) 95 low-frequency items. Items were selected (i) as providing a range of difficulty based on the accuracy scores of Burt and Tate's participants and (ii) as being likely to be part of university students' vocabulary (both native and non-native alike). The list of words is provided in the Appendix. The set-up was the same as for the novel word spelling task, with one laptop computer for stimulus presentation and one for typing. Participants first listened to the target word in isolation and, for disambiguation, in a sentence context (taken from the online Oxford English Dictionary), recorded by the same male native speaker of American English who also recorded the experimental stimuli; then they typed the target word into the text editing programme on the second computer before moving on to the next word. Participants were asked to double-check their answers to avoid typos.

Additionally, participants completed a short standardised lexical decision experiment, the *LexTALE*[4] (Lemhöfer and Broersma 2012), to measure their vocabulary size in English and indicate general English proficiency. This was also implemented in DMDX and participants indicated with a button press on a gamepad whether or not the string of letters presented on the computer screen was an existing word in English or not. Targets were presented in white writing on a black background and stayed on screen until the participant pressed a button. This task took approximately 5 minutes.

4 Results

4.1 Participant characteristics

As described above, two measures of participants' language skills were taken: Spelling ability and vocabulary size as measured with the LexTALE task. First, for the spelling ability measure, the percentage of correct spellings was calculated. Morphologically related versions of the target words (e.g., plurals: *antecedents* instead of *antecedent*; derived forms: *recurrent* instead of *recurrence*, *adherence* instead of *adherent*) were also accepted as correct responses. A summary of participants' spelling ability and other participant characteristics is provided separately for the experienced (i.e., English native speakers) and inexperienced spellers (i.e., students of English) in Table 1, including a significance test for group differences. As can be seen from the means, the experienced and inexperienced speller groups differed significantly, with the experienced group having a higher mean score. However, both groups displayed a wide range of spelling ability scores, covering a similarly wide range. Although there were more inexperienced spellers at the low end of the scale, 26 of the inexperienced spellers reached scores of 50 percent or more, showing a similar spread across the scale as 32 of the experienced spellers.

Second, with respect to the LexTALE scores, a similar picture emerged for the two groups: While the experienced spellers had significantly higher LexTALE scores compared to the inexperienced ones, there were individuals in each group that scored low or high on the scale, covering a wide range. In order to capture this distribution of vocabulary size across the two groups, LexTALE score was used as a continuous variable in the model rather than artificially dividing participants into groups based on their language background.[5]

4.2 Novel word spelling

Before analyses, three types of data points were removed: (1) missing data (N = 1), (2) productions of existing words that may have been accidental (e.g., /vʌʃəs/ being spelt ‹bushes›, potentially with the vowel sound from words like ‹bus› rather than

[4] Available online at www.lextale.com.

[5] Note that using a categorical distinction between experienced and inexperienced spellers instead yielded the same effects as reported below (minus an effect of Age of Acquisition (AoA), which is not meaningful once the native speakers (i.e., the group with an AoA of 0) is separated).

Table 2 Number of occurrences for different spellings in total and divided by context (adjective vs. noun context); affix spellings bolded [N.B.: The category "other" comprises those spellings that occurred less than 10 times.]

Spelling	Number of occurrences		
	Total	Adjective context	Noun context
‹us›	659	310	349
‹ous›	**317**	**208**	**109**
‹is›	301	125	176
‹es›	129	70	59
‹ess›	74	20	54
‹ice›	71	34	37
‹ious›	**53**	**29**	**24**
‹eous›	**49**	**36**	**13**
‹less›	29	20	9
‹iss›	25	10	15
‹est›	24	11	13
‹uss›	22	11	11
‹ness›	17	7	10
‹as›	15	10	5
‹ace›	11	4	7
‹ist›	11	2	9
other	65	34	31
Total	1872	941	931

the phoneme /ʊ/) or sounded similar to the novel words to a certain degree (e.g., ‹lazes› /leɪzəs/ for /læzəs/, N = 33), and (3) productions that started with the letter ‹a›, indicating that participants interpreted the article *a* in the noun condition as part of the novel word, essentially resulting in this context sentence being an adjective context for the affected trial (N = 14). This resulted in the removal of 2.5 percent of the data.

Participants' productions were analysed with respect to which letters were used to spell the final /əs/ sequence of the critical items. As can be seen in Table 2, which lists the number of occurrences for all spellings that appeared at least 10 times, the most common spellings were ‹us›, ‹ous› and ‹is›, together accounting for approximately two thirds of all spellings. In addition, the table also shows the distribution in the two different contexts, with all of the listed spellings being used in both contexts. With respect to the spelling of interest, while participants spelt the novel words with ‹ous› or its allomorphs ‹ious› or ‹eous›[6] in both the adjective (273 out of 941 novel words = 29%; see bolding in Table 2) and the noun context (146 out of 931 novel words = 16%), the likelihood of a participant choosing the ‹ous› spelling was two to one in the adjective compared to the noun context (i.e., 65% of the 419 ‹ous› spellings appeared in the adjective context).

[6]The allomorphs were included in the count for the affix spelling because properties of the preceding phoneme can affect the spelling of the affix *-ous*. For instance, the sequence /ʃəs/ is nearly always spelt with ‹ious› (e.g., *precious*, *gracious*, *ambitious*) or sometimes ‹eous› (4 cases in CELEX: e.g., *curvaceous*, *herbaceous*), with only two exceptions in CELEX (i.e., the names *Confucius* and *Mauritius*).

In order to test whether the observed differences for the spelling of interest, namely ‹ous›, in the two contexts are statistically reliable, data were analysed with a generalised linear mixed-effects model (GLMM) with a logit link function, using the lme4 package (version 1.1-19, Bates et al. 2015) in R (version 3.4.1, R Core Team 2017). The dependent variable (DV) was whether or not the final sound sequence was spelt with ‹ous› (1: ‹ous›,[7] 0: other spelling). The fixed effect of interest was Context (Adjective vs. Noun; sum-coded). Furthermore, the centred factors Trial Number, Spelling Ability, LexTALE Score, Age of Acquisition (AoA) and Age were included as fixed effects to control for potential learning or fatigue effects and individual differences respectively. In order to test for individual differences based on spelling ability (as suggested by previous research) as well as to control for potential effects of a later age of acquisition (AoA) of English on the experimental manipulation, it was tested if the inclusion of an interaction of the factors Spelling Ability, LexTALE Score and AoA respectively with Context was justified. Only the interaction between Spelling Ability significantly improved model fit and was thus included. After the fixed effects were established, the inclusion of Trial Number and Context in the random slopes was tested, leading to a random slope structure with Trial Number as by-participant random slope.

As the original model did not converge due to complete separation[8] in the data (e.g., there were participants who never used an ‹ous› spelling in the adjective context and others who always did), a weakly informative prior was introduced to the fixed-effect parameters, using the blme package (version 1.0-4, Chung et al. 2013) in R. Such a prior still allows for the detection of large effects, while reducing the probability of the kind of extremely large differences that can cause problems in model convergence. The prior for all fixed effects was a normal distribution with a mean of 0 and a standard deviation of 3; this means that 95% of the prior distribution was between -6 and 6 in the log-odds scale, which is still a large effect.

The output from the statistical analyses is provided in Table 3. There was a main effect of Context ($p < .001$), reflecting the fact that participants produced more ‹ous› spellings in the adjective ($M = 29.01\%$) compared to the noun context ($M = 15.68\%$). Crucially, there was an interaction with Spelling Ability,[9] suggesting that ‘better’ spellers were influenced by the context manipulation to a higher degree than ‘poorer’ spellers. Figure 1 visualises this interaction by plotting the difference between the percentages of ‹ous› spellings in the adjective versus noun context for each participant on the y-axis against their spelling ability score on the x-axis. The higher the spelling ability score, the more likely were participants to spell novel words in the adjective context with ‹ous› while not doing so in the noun context (or at least only to a lower degree).[10]

[7] Note that this count included the allomorphs ‹ious› and ‹eous›.

[8] For cases of complete separation, Firth (1993) proposed a penalised or bias-corrected solution, which can be implemented for GLMMs by introducing a weak prior to the fixed-effect parameters (Gelman et al. 2008; Abrahantes and Aerts 2012).

[9] Note that interactions with LexTALE score and AoA were not included in the model because they did not significantly improve model fit.

[10] Note: The same pattern of results emerged when other adjectival affixes (i.e., ‹less› and ‹ish›) were included in the dependent variable.

Table 3 Model estimates from GLMM with weakly informative prior for production of ‹ous› spellings [N.B.: Intercept is the grand mean; factors reflect main effects.]

	Estimate	SE	*z*-Value	*p*-Value
(Intercept)	−2.3690	0.3304	−7.17	<0.001*
Context (ADJ vs. N)[s]	1.3638	0.1628	8.38	<0.001*
Spelling Ability[c]	0.3323	0.3641	0.91	0.361
Trial Number[c]	0.2704	0.1239	2.18	0.029*
LexTALE Score[c]	0.0827	0.4088	0.20	0.840
AoA[c]	0.7386	0.3027	2.44	0.015*
Age[c]	0.0199	0.2684	0.07	0.941
Context (ADJ vs. N)*Spelling Ability	0.5139	0.1749	2.94	0.003*

Formula in R: DV ~ Context * SpellingAbility + Trial + LexTALE + AoA + Age + (1+Trial|Part) + (1|Item)

[s] sum-coded: ADJ +0.5; N −0.5

[c] centred

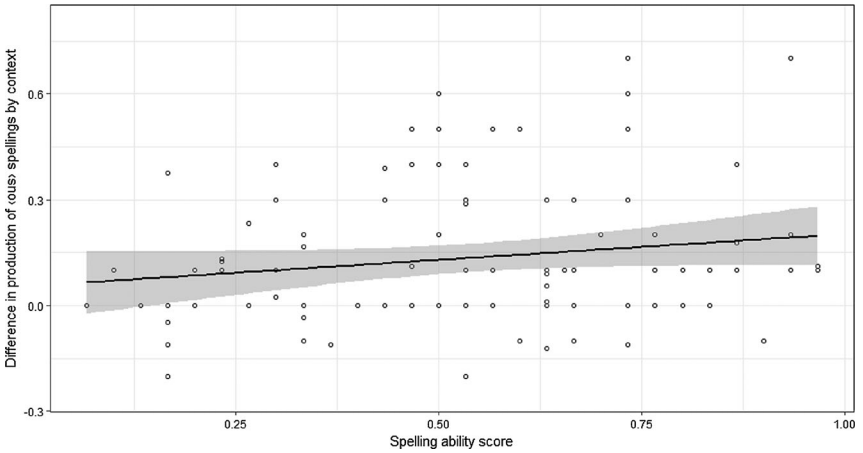

Fig. 1 Each participant's production of ‹ous› spellings in the adjective versus noun context (percentage of ‹ous› spellings in adjective context minus percentage of ‹ous› spellings in noun context) plotted against spelling ability score

In addition, there were effects of Trial Number ($p = .029$) and AoA ($p = .015$), with the positive estimates indicating that (a) participants were more likely to produce ‹ous› spellings later in the experiment and (b) participants who were exposed to English later on spelt more words with ‹ous› overall than those exposed to English earlier.

5 Discussion

The present study found that participants were more likely to spell novel /əs/ words with the affix spelling ‹ous› when it appeared in an appropriate adjective context

than when it appeared in a noun context, suggesting that participants were aware of the implicit morpho-graphic regularities of the English spelling system. The spelling ‹ous› thus indicates adjectivehood of novel words and is less likely to be used in an inappropriate noun context.

However, although the modifications to the design (compared to Ulicheva et al.'s (2020) set-up) made the grammatical context much more transparent and predictable, aiming at increasing the application of morpho-graphic spellings, the percentage of ‹ous› spellings was still rather low. If the implicit rule assigning adjective status to ‹ous› spellings was administered mirroring the occurrence in existing words (as revealed by Berg and Aronoff's (2017) corpus analysis), it should have been used to a higher percentage than the actual 29% in the adjective context and it should never have occurred in the noun context (where it was used 11% of the time). This pattern of ‹ous› occurrence replicates Ulicheva et al.'s (2020) relatively low percentage of ‹ous› use (also 29%). So, despite the fact that participants in the present study heard the novel word embedded in the context auditorily (rather than hearing only the novel word in isolation) in addition to seeing the context sentence on the screen, participants might still have paid little attention to the context sentence, waiting for the novel word instead. In a recent study, Treiman et al. (2020) implemented another method to make participants actively engage with the context sentence: Participants had to write down the context sentence including the novel word. However, Treiman et al.'s participants spelt words with ‹ous› even less often, with only 12% of ‹ous› spellings in the adjective context.

Nevertheless, participants in the current study showed awareness of the grammatical context – also with respect to other morphological spellings that were produced. More specifically, a similar representation of the novel words' grammatical category can be observed for ‹less› and ‹ess›. While the adjectival affix spelling ‹less› (as in *harmless*) mainly appeared in the adjective context (20 out of 29 occurrences), the nominal affix spelling ‹ess› (referring to female humans or animals such as *hostess* or *lioness*) shows the opposite pattern, with 73% of occurrences (54 out of 74) being in the noun context.

Additionally, with respect to the affix spelling ‹ess›, more than simply lexical category information might affect the spelling choices: The spelling ‹ess›, which may represent the nominal affix *-ess*, was more likely to be used in context sentences with a female subject (i.e., *she* as subject in the context sentence: 44 out of 54 occurrences in the noun context), indicating that participants' choices may have been influenced by semantic information of the suffix *-ess*, which refers to females rather than males.

Of the possible alternative spellings, the ‹us› variant was by far the most common – used even more often than the morpho-graphic ‹ous› spelling, which has a higher type frequency in the existing English vocabulary (cf. Berg and Aronoff 2017). This was predicted based on Berg and Aronoff's corpus analysis, which found ‹us› to be the most frequent alternative spelling.

The high ratio of ‹us› compared to ‹ous› spellings could be due to participants' reluctance to make the novel words look like morphologically complex words. If the letter sequence ‹ous› is seen as an affix, participants might expect the novel words to be derived from a base they are familiar with. In the novel words in the present study, this base could not have been identified. To further investigate this possibility, future research could work with a design that introduces both bases and complex forms.

In contrast, participants could also adopt an analogy strategy due to influence of the lexical route during novel word spelling. Participants might search the mental lexicon for entries that match the input string most closely and apply the same spelling. As the present study did not systematically manipulate novel words' similarity to existing words, the present data cannot give a definite answer to this option. However, when looking at the two experimental items that had one or two phonological neighbours, a potential effect of analogy might be visible in that the word ‹vushus› indeed yielded a large number of ‹ious› spellings as in its neighbours *luscious* and *vicious* irrespective of context (adjective context: 17, noun context: 15, other spellings: 8 or fewer occurrences). In the case of ‹purnus›, though, there were no analogous spellings with ‹ose› as in its neighbour *purpose*.

Analogy could also operate at smaller units than words. As Kessler and Treiman (2001) showed, the spelling of vowels depended on the following coda. This might potentially also apply to larger units such as final syllables. For instance, with respect to the final sequence /ʃəs/ in the above example ‹vushus›, a search in webCELEX revealed that 92 percent of all words ending in this phoneme sequence (91 out of 99 types) are spelt with ‹ious›, which could explain the observed preference for this spelling. Future research should systematically manipulate grapheme-phoneme consistency of larger final phoneme units to investigate the contribution of analogy to novel word spelling.

With respect to the predicted modulation by spelling ability and experience with the English writing system, the present study revealed an influence of spelling ability in that participants who performed better at the 30-item spelling task were more likely to spell the critical novel words with ‹ous› in the adjective context than in the noun context, indicating that the regularities are gradually induced from the input, which results in more robust rule application with increased experience and expertise in the English writing system. This finding is in line with Kemp and Bryant's (2003) observation that adults with university education (i.e., a large amount of reading and writing) were better at using morphological context in the spelling of novel plural nouns ending in a vowel plus /z/ with the appropriate morphological spelling ‹s›. Treiman et al. (2020), on the other hand, did not find a modulation of their effect by spelling ability as measured with the spelling subtest of the Wide Range Achievement Test (WRAT, Wilkinson and Robertson 2006), which the authors argue might be due to the range of spelling scores not being large enough. The present as well as Kemp and Bryant's findings suggest that for 'better' spellers the implicit morpho-graphic spelling regularities are more consolidated, allowing those spellers to make better use of the context information in connection to the spelling. In general, these spellers appear to be able to better integrate different sources of information because, due to automation, fewer resources are required for the individual processes.

Interestingly, an influence of spelling ability has also been reported with respect to morpho-orthographic priming in morphological processing research. Previous masked priming research has shown facilitation effects for primes that are not morphologically related to their targets but appear to have an affix (e.g., *corner* – *corn*), with participants 'stripping off' ‹er› in the earliest processing stages and accessing the supposed stem (e.g., Rastle et al. 2004). Andrews and Lo (2013) found

this so-called *corner-corn* effect to be stronger for 'good spellers', indicating that these participants with an 'orthographic profile' were more likely than 'poor spellers' to (incorrectly) identify the letter sequence ‹er› as affix.

In connection to the above point about spelling ability, the main effect of AoA suggests that spelling behaviour might depend on the type of exposure to the writing system. Overall, participants who had been exposed to the English writing system later were more likely to produce ‹ous› spellings (irrespective of context). Considering the fact that learners of English have already acquired one writing system (namely that of their first language) and are usually exposed to written forms of English from the beginning of their acquisition process, second language learners may have a head-start in consolidating orthographic representations within lexical entries and in noticing morpho-graphic spelling regularities, while, for native speakers, the orthographic representation is added later and needs to be mapped to phonological statistics that are already consolidated. This stronger focus on orthographic information has also been shown in masked priming research with late learners, who showed significant facilitation for purely orthographically related prime target pairs such as *scandal – scan*, while such pairs do not cause priming in native readers (cf. Heyer and Clahsen 2015; Li et al. 2017).

Other participant-level factors that might play a role are morphological awareness and phonological decoding ability. In other words, for participants to actually produce the appropriate spelling, they first have to realise that the sentence context requires an adjective (versus a noun) and then need to segment the phoneme sequence /əs/ from the input. With respect to the former, Nunes et al. (1997a, 1997b) found that participants with higher scores on the morphological awareness tests were more likely to be on a higher stage in their 5-stage model for word-final /d/ and /t/. So, future research should take these other participant-level factors into consideration in addition to spelling ability.

There might also be item-level factors influencing the application of morpho-graphic spelling regularities: Productivity and transparency of the affix in question. With respect to the first, participants might be able to induce spelling characteristics from the input more easily if the affix in question appears with many different bases. For example, although ‹ous› is a very reliable indicator for adjectivehood (Berg and Aronoff 2017), the affix is not very productive, with a large number of *-ous* adjectives having bound roots and/or being of Latinate origin (e.g., *audacious*, *hilarious*, *tremendous*; cf. Plag 2003:97). As a result, spellers might be less aware of its status as an adjective marker and thus take longer to induce the regularity compared to very productive affixes such as *-ness*.

Similarly, participants might more easily identify a suffix and its spelling regularities when it is transparent. Different suffixes might vary with respect to how consistent and transparent the added semantic information is. For instance, the suffix *-ise* adds a different meaning in *hospitalise* ('to put someone into hospital') compared to *vaporise* ('to turn something into vapour') and the agentive meaning of *-er* in nouns such as *baker* or *runner* might be more transparent than the quality meaning of *-ous* adjectives. Future research should systematically compare different types of affixes.

6 Conclusion

The present study showed that English spellers are aware of implicit morpho-graphic spelling regularities and apply them to the spelling of novel words. However, the extent to which they do so depends on individual differences: The better a speller someone is—irrespective of when the exposure to the spelling system started, the more likely one is to apply morpho-graphic spelling regularities in novel word spelling. For this application, two conditions have to be fulfilled: Spellers need to have induced the regularities from the input in the first place, which requires sufficient exposure to the writing system, and they need to integrate different types of information in the actual spelling event (e.g., the lexical category required by the sentence context). Both of these processes should be aided by better spelling abilities because the automation of the spelling process will lead to reduced processing load, freeing up resources for other processes (such as the integration of context information).

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Appendix

Table A1 Experimental items

Form	IPA transcription	Form	IPA transcription
bormus	bɔːrməs	monsus	mɔːnzəs
cradus	krædəs	ninkus	nɪnkəs
dribus	drɪbəs	purnus	pɝnəs
duttus	dʌtəs	roldus	rɔːldəs
fincus	fɪnkəs	shofus	ʃɔːfəs
flupus	flʌpəs	snitus	snaɪtəs
fripus	fraɪpəs	sturus	stɝəs
hupsus	hʌpsəs	trinus	trɪnəs
lazzus	læzəs	vushus	vʌʃəs
lorkus	lɔːrkəs	weegus	wiːgəs

Items to measure spelling ability (selected from Burt and Tate's (2002) Experiment 3)

accomplice; adherent; aggravate; annihilate; antecedent; assessor; assimilate; colloquial; conciliate; digestible; diligent; gullible; innuendo; insatiable; insolent; invincible; lingerie; oblivion; omniscient; parachute; pinnacle; plagiarism; recurrence; repetitive; rigidity; subtlety; succinct; tranquil; vehicular; vigilant

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